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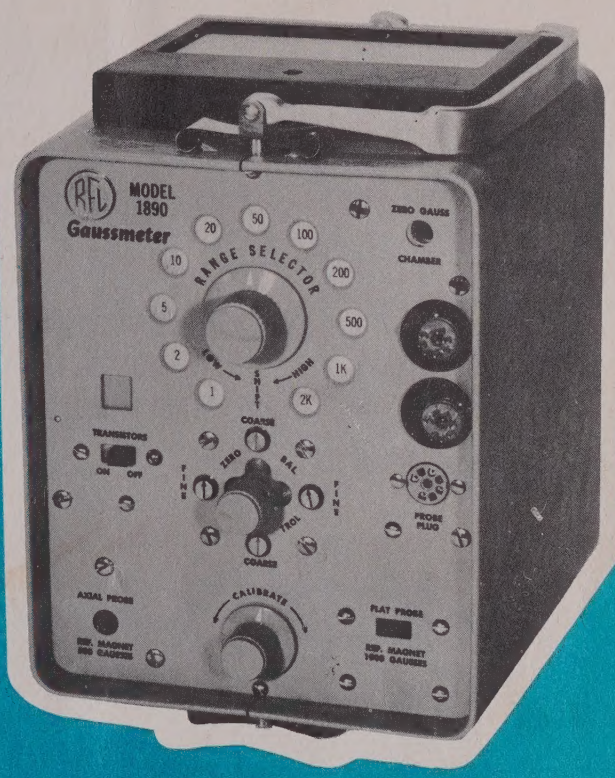
Manual of Instructions



RFL

Gaussmeter

Model 1890

Radio Frequency
LABORATORIES, INC.
Boonton, New Jersey, U.S.A.

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Designers and Manufacturers of Electronic Equipment since 1922

THIS BOOK TO BE USED WITH EQUIPMENT

SERIAL NO. 983

Manual of Instructions

Model 1890 Gaussmeter

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BOONTON, NEW JERSEY, U.S.A.

Book No. MA-13300E

DESIGNERS & MANUFACTURERS OF ELECTRONIC EQUIPMENT SINCE 1922

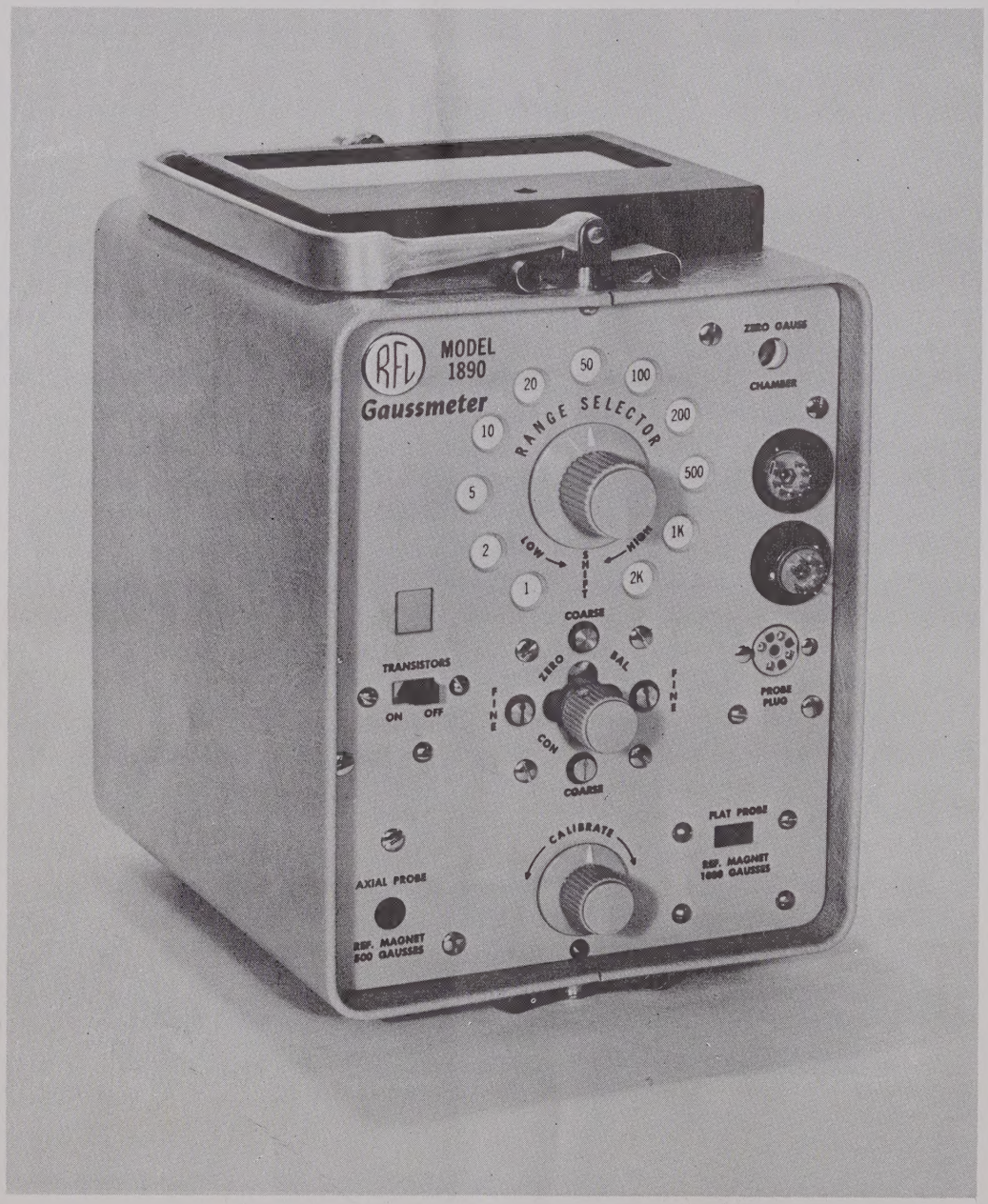


Figure 1. Front View of Model 1890 Gaussmeter.

General Description

PURPOSE

The Model 1890 Gaussmeter was developed to measure magnetic fields from 0.1 to over 20,000 gausses.

The equipment operates on the Hall effect principle, enabling a measuring probe of small physical size to be used for measuring flux densities. The probe element is indium arsenide, selected for best linearity and temperature stability. The use of transistors reduces equipment warm-up time to a minimum, and permits economical battery operation for portable or field use in addition to AC line operation.

The Model 1890 provides a rapid means of checking magnetic instruments at any stage of their assembly. It is a complete instrument for making direct measurements of gap flux density in normal or axial fields, and analyzing location, homogeneity and intensity of stray fields. It permits both quantitative and qualitative checking of design formula predictions.

DESCRIPTION

The equipment is enclosed in a gray vinyl covered aluminum cabinet measuring $8\frac{1}{2}$ inches high by 6-3/4 inches wide by 8 inches deep, and weighs 12 pounds. All operating controls are located on the front panel except for the AC Supply ON-OFF switch which is mounted on the supply. The large meter, calibrated directly in gausses, is mounted on the top of the case, as shown in Figure 3, and can be raised to 45° and 60° positions for easy reading from the front of the instrument, or can be removed and placed in the work area as shown in Figure 6. For this facility the meter is a core magnet type, equipped with mirror scale and knife edge pointer, producing practically no stray fields to affect measurements made close to it. The meter mechanism provides better than 0.5% repeatability, while its long scale and linear divisions allow for better than .01 gauss resolution of reading on the lowest scale.

The electrical circuits are divided into major functions and are packaged in modular cases which provide effective electrostatic and magnetic shielding. Service or parts replacement is relatively simple. Access to these assemblies is quickly accomplished by removing either, or both, halves of the cabinet; these are held in place by two spring tension retainers.

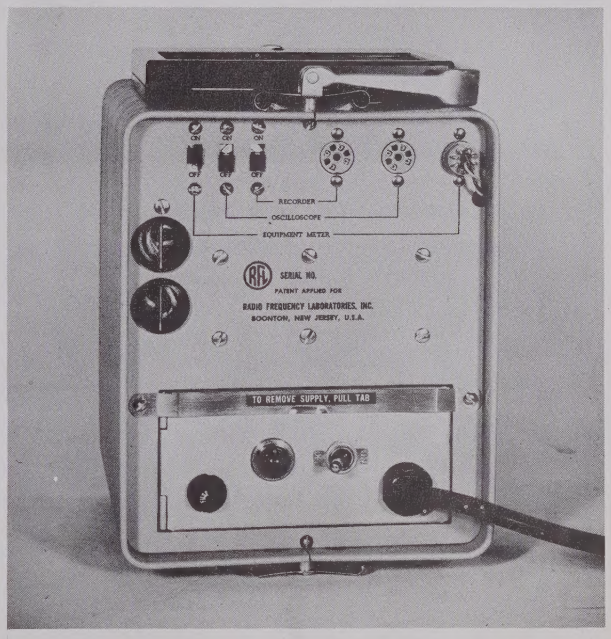


Figure 2. Rear View with AC Power Supply.

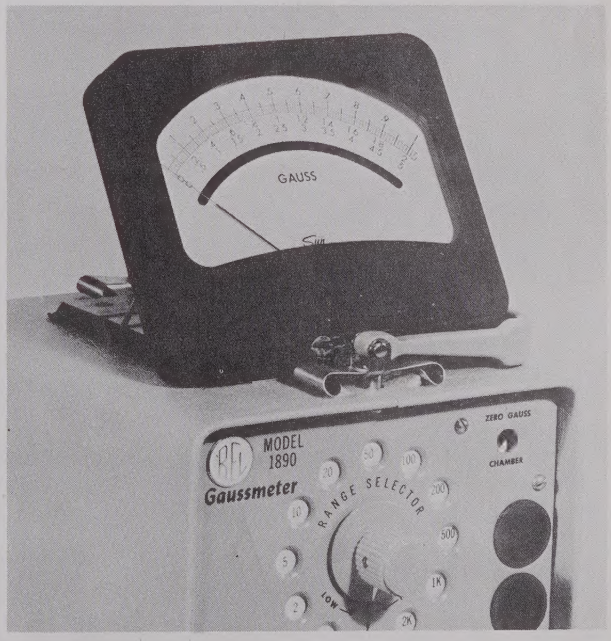


Figure 3. Meter Raised.

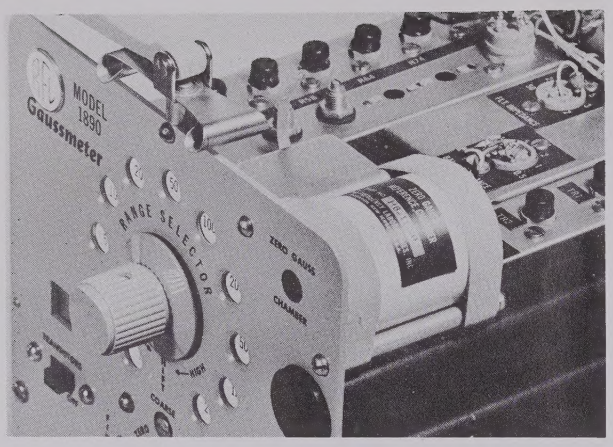


Figure 4.
Location of 0-Gauss Chamber

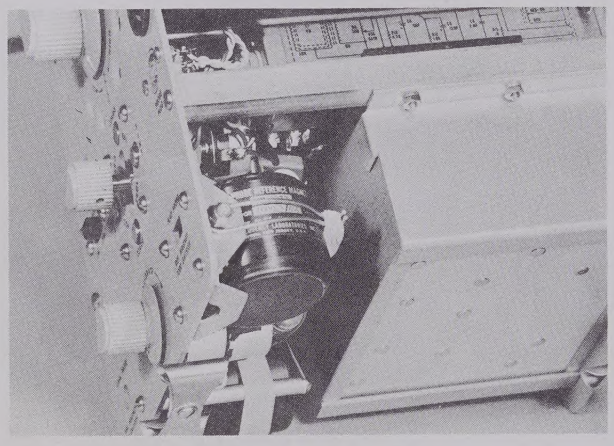


Figure 5.
Location of Flat Probe Reference Magnet.

Seven control functions are accomplished through operation of only three knobs mounted on the front panel. These controls are the ZERO BAL. CONTROL, CALIBRATE and the RANGE SELECTOR switch which provides a selection of fourteen, overlapping full-scale ranges divided into two groups: a LOW of eleven ranges from 1 gauss to 2000 gausses and a HIGH of eleven ranges from 10 gausses to 20,000 gausses. Range switch settings are in two colors: black for LOW, red for HIGH. Each range position is indicated in digits for error-free selection of full-scale sensitivity desired. The shift from LOW to HIGH is made by turning the RANGE SELECTOR to the full bottom position, going counterclockwise for LOW shift or clockwise for HIGH shift. The scale will shift showing red or black digits for the ranges required.

Space is provided for mounting two reference magnets inside the cabinet with access from the front. One will accommodate the basic 1000-gauss HB-9272 magnet for calibrating flat probes; the other accepts the standard 500-gauss reference magnet for calibrating axial probes.

To provide accurate probe zero balance, a shielded Mu-metal cavity (0-gauss chamber) is provided and is also accessible through the front panel; so that stray magnetic fields, including the earth's field, can be prevented from affecting zero balance on the lower ranges. As shown in Figures 4 and 5, the 0-gauss chamber and probe reference magnets are held in place by flexible bands and can be removed easily to be placed on the work surface in front of or beside the Gaussmeter, whichever is most convenient.

Space is also provided for storing two axial probes inside the unit with access through the front panel for convenience. The more delicate flat probes should be kept in the plastic box.

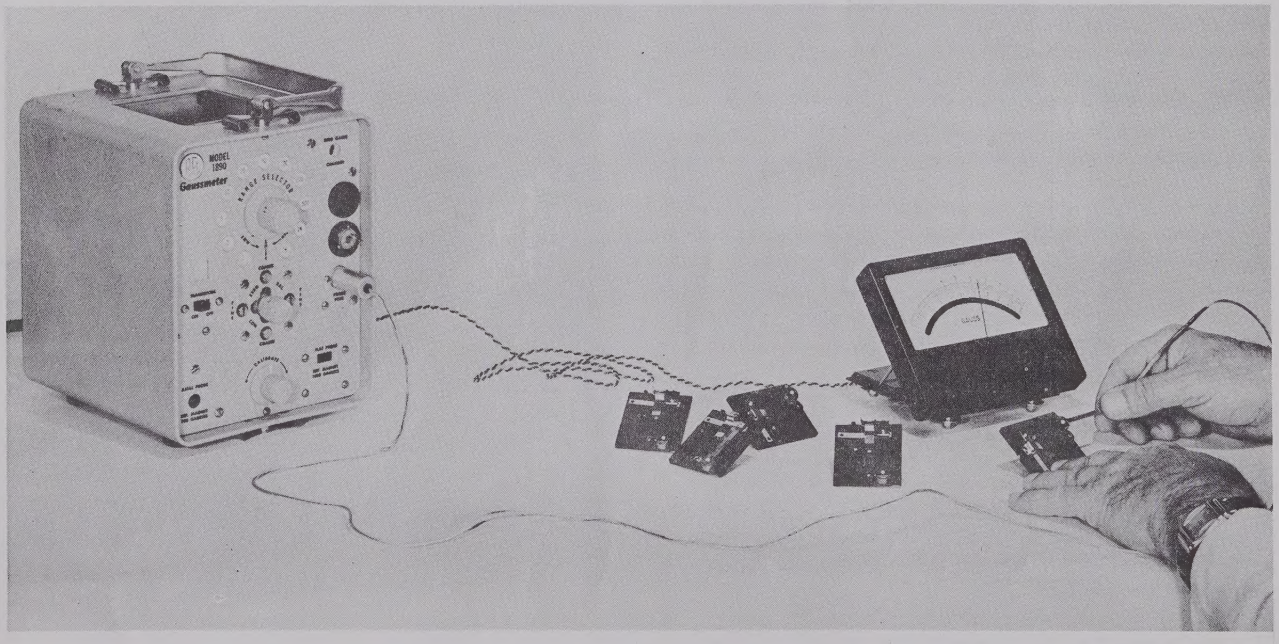


Figure 6. The Meter of Model 1890 Removed from Cabinet.

PROBE REFERENCE MAGNETS

Stable, accurate permanent reference magnets are the heart of any magnetic flux measuring system which employs the Hall effect. Semi-conductor elements have not yet been discovered that are completely linear in response or whose sensitivity remains constant over the years. To yield a system accuracy within ±3% a properly designed and calibrated reference magnet is a necessity. RFL reference magnets are coaxial in form to eliminate stray fields in the area of measurement and to prevent magnetic change in the reference when contacting other strong magnets. The pole faces are accurately machined of special alloys to provide a uniform flux distribution. All reference magnets are stabilized and adjusted to full-scale values using mutual inductors and search coils having National Bureau of Standards certificates. Table 1 shows the approximate errors involved in the standardization of a ±3/4% reference magnet.

The 1000-gauss HB-9272 (±0.75%) reference magnet is basically required for all flat probes and the 500-gauss value (±1.5%) must be used with all axial probes. In the latter case, there is a type for each probe diameter. In addition to the two basic values, reference magnets having values from 5 to 20,000 gausses can be supplied. Some of these are listed below.

PART NO.	VALUE	GAP
HB-9272	200 and 500 gausses (±1.5%)	.062"
HB-9272	1K, 2K or 5K gausses (±0.75%)	.062"
HB-9657	10,000 gausses (±0.75%)	.040"
HB-16582	20,000 gausses (±0.75%)	.040"
HB-16578	10,000 gausses (±0.75%)	.062"
HB-16572	100, 200 or 500 gausses (±1.0%)	.156"
HB-16574	1000 or 2000 gausses (±0.75%)	.156"
HB-16576	5000 gausses (±0.75%)	.156"
HB-16655	5, 10 or 20 gausses (±1.5%)	.343"
HB-16570	50, 100 or 200 gausses (±1.0%)	.343"
HB-16660	500, 1000 or 2000 gausses (±3/4%)	.343"
HB-11279	500 gausses (±1.5%)	5/16" dia.
HB-11279	500 gausses (±1.5%)	.200" dia.
HB-11279	500 gausses (±1.5%)	5/32" dia.
HB-11279	500 gausses (±1.5%)	.100" dia.

Table I.

Limits of Error
in the Calibration of a ±3/4% Reference Magnet

Error	Description
±0.25%	Bureau of Standards accuracy of calibration of search coil.
±0.05%	Bureau of Standards accuracy of measurement of mutual inductor.
±0.10%	RFL accuracy of measurement of DC current.
±0.20%	RFL fluxmeter transfer reading error.
±0.15%	Non-uniformity of field in gap.
±0.75%	Maximum error

PROBES

Both the flat and axial probe types are constructed of non-metallic glass reinforced epoxy and are equipped with light, flexible cables for probing narrow apertures with a maximum sense of "feel" for the delicate element embedded in the tip. A typical flat probe for measuring transverse fields and a cylindrical probe for magnetic fields parallel to its long axis are shown in Figures 7 and 8. Standard cables are 5 ft. long with extension cables available up to 50 ft. in length. Presently available, standard InAs probes are:

HB-13460	Flat .025" thick x 13/64" wide x 1" long
HB-13475	Flat .020" thick x 1/8" wide x 9/32" long
HB-13477	Tangential .040" thick x 13/64" wide x 1" l.
HB-15950	Flat 1 mm (.039") thick x 13/64" x 1" long
HB-13470	Axial 5/16" diam. w/5 ft. cable
HB-13472	Axial 0.20" diam. w/5 ft. cable
HB-11261	Axial 5/32" diam. w/5 ft. cable
HB-13482	Axial 0.10" diam. w/5 ft. cable

Flat probes should be handled carefully and stored in their plastic box when not in use. The InAs element is extremely brittle and should never be subjected to squeezing or bending.

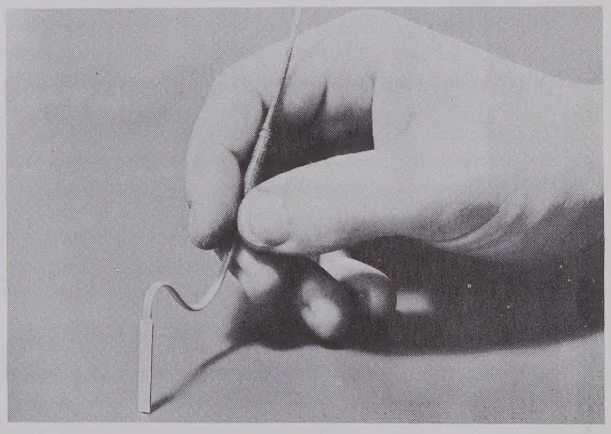


Figure 7.
Typical Flat Probe Showing Flexibility of Cable.

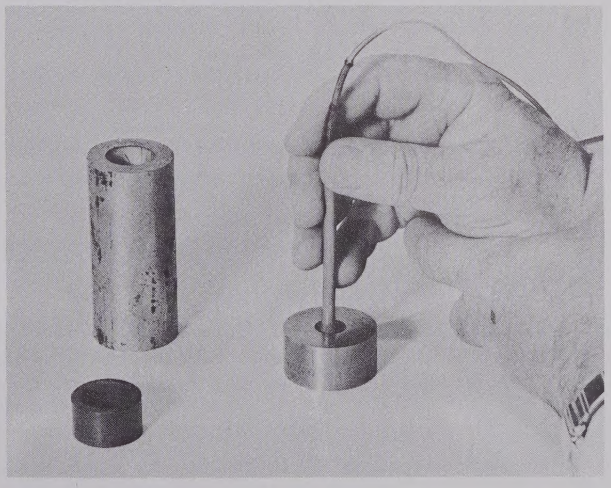


Figure 8.
Typical Axial Probe.

ELECTRICAL FEATURES

Each probe is supplied with a test data sheet which contains electrical and temperature stability values measured for that probe, plus calibration data for each range as measured using laboratory standard reference magnet fields for each full-scale range. Since sensitivity of InAs decreases above 10,000 gausses, down-scale data are particularly necessary on the 20,000-gauss range. This characteristic permits use of the 20,000-gauss range in making measurements above 20,000 gausses. Where maximum accuracy is desired between 10,000 and 30,000 gausses, two calibration options are available at extra cost. These options are more fully described under the Section on OPERATION.

For research work and special applications, the oscillator output transformer and the amplifier input filter are provided with a series of taps which permit 2 to 50 ohms adjustment to various probe impedances. These taps are push-pin connections (see Figure 20) and, by making these adjustments, engineers can use the Model 1890 to measure the Hall coefficients of materials at low field intensities. These facilities also prevent the instrument from becoming obsolete as various Hall effect materials are discovered and put in use.

The modular, unitized construction allows the use of the various subassemblies for research projects or rearrangement for relay rack mounting or special packaging.

The Gaussmeter amplifier is linear and powerful enough to drive an external recorder. There are three output plugs on the back panel, as shown in Figure 2, for an external recorder, oscilloscope and meter. These plugs can be switched consecutively into the Gaussmeter circuit by the three slide switches on the back panel.

POWER SUPPLIES

The equipment is supplied, as ordered, for battery or AC line operation.

The Battery Supply HB-13,375 and the AC Power Supply HB-13,350 are the same size and are easily installed or exchanged without tools. For normal laboratory or field use, battery operation is most convenient. For continuous laboratory or production use, the AC power supply is recommended.

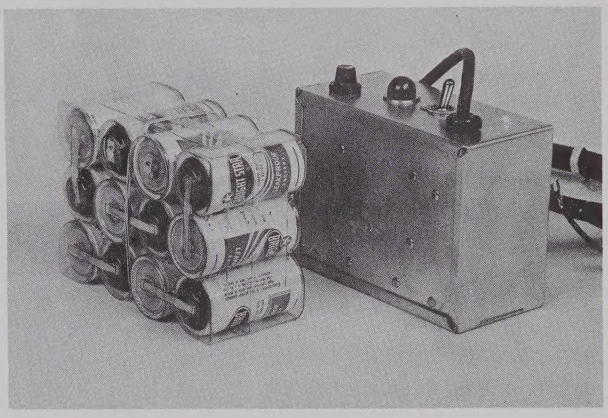


Figure 9. Plug-in Power Supplies.

Table 2.

TECHNICAL DATA SUMMARY

RANGES

0 to 1, 2, 5, 10, 20, 50, 100, 200, 500, 1K, 2K, 5K and 10K gausses full-scale direct reading; to 20K gausses using probe calibration data supplied; to 30K gausses using 10K-gauss ref. magnet and curve (Option "B" at additional cost).

ACCURACY

±1% plus accuracy of reference magnet using probe calibration data supplied; within ±3% direct reading over 1 to 10K-gauss ranges and to 20K gausses using probe calibration data and 1000-gauss ref. magnet supplied.

TEMPERATURE STABILITY

Temperature deviations with InAs probes supplied are less than 1% change of sensitivity and less than one gauss zero shift for 10°C element temperature change.

MAGNETIC FIELD FREQUENCY

Magnetic fields from DC to 400 cps. can be measured.

OSCILLOSCOPE OUTPUT

2.0 volts max.; display includes 3000 cps. carrier signal.

EXTERNAL RECORDER OUTPUT

1.0 milliampere DC into 1500 ohms maximum.

SUPPLY VOLTAGE

With Battery Supply HB-13,375:

Holds 12 standard D-size, 1.5-volt flashlight cells (supplied) which provide more than 100 hours of intermittent 4-hour per day operation.

With AC Power Supply HB-13,350:

115/230 volts, 50/60 cps. Output 18 volts DC at 18 MA.

SIZE & WEIGHT

8½" high x 6-3/4" wide x 8" deep.
12 lbs.

Theory of Operation

THE HALL EFFECT

When electrons move in a conductor perpendicular to a magnetic field, they are deflected toward one side of the conductor (left or right depending on the direction of the magnetic field) in a direction normal to the direction of both the initial electron flow and the magnetic field. The force deflecting the electrons is directly proportional to the electron velocity (current) and the magnetic field intensity. This deflection process continues until sufficient charge has accumulated at the sides of the conductor to establish a transverse electric field which opposes further deflection of charge carriers. The transverse potential difference thus created is called the Hall voltage and the phenomena causing it, the Hall effect.

The magnitude of this potential in volts is given by the equation:

$$E = \frac{RIH}{t},$$

where I is the current in amperes, H is the magnetic field strength in gausses, t is the thickness of the sample in centimeters, and R is the Hall coefficient in volt-cm/ampere gauss.

Under the conditions shown in Figure 10, the terminal B will be negative with respect to terminal A for metals and semiconductors in which the current is carried by electrons. Reversing the field reverses the output polarity. As shown by the equation above, the width of the strip is not a factor of the output as long as it is large compared to the thickness. The strip should be twice as long as it is wide or the output drops off. For thin strips the output is unaffected by the frequency of the field in the audio range. The Hall voltage is maximum when the plane of the element is perpendicular to the magnetic field.

Practical materials for Hall elements are films and slabs of specially refined semiconductors. The sensitivity, temperature stability and linearity to fields can be varied through wide ranges by selection of materials. One characteristic can usually be improved at the expense of the other characteristics. Hall elements made of InAs, InSb and other similar III-V compounds require a loading resistor across the Hall contacts for best linearity in strong fields above 2000 gausses. This resistor is determined experimentally for each element.

The flat and axial probes for the Model 1890 Gaussmeter are manufactured using a very thin piece of InAs which is selected for use in the temperature range of 32°F to 165°F.

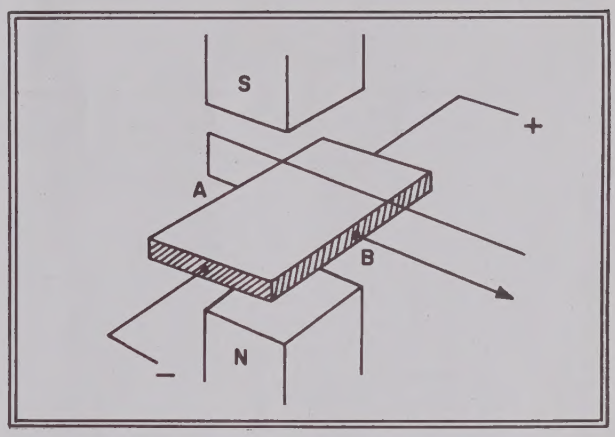


Figure 10.
Schematic Circuit Arrangement for the Measurement of the Hall Coefficient.

CIRCUIT ARRANGEMENT

The block diagram of Figure 11 shows the arrangement of circuits in the equipment. The 3000-cycle oscillator is designed to supply a constant current to the current terminals of the probe element. The potential leads are brought from the probe to a 3000-cycle filter with a 1000-cycle bandwidth. A balancing network is provided to inject a small voltage into the pickup loop to balance out the residual resistive unbalance in the probe. The ZERO BAL. CONTROL on the front panel adjusts the phase and magnitude of this injected voltage. The purpose of the filter is to remove harmonic voltage from the signal as generated in the 3-kilocycle oscillator and step the voltage up by a factor of ten. An 11-step attenuator permits measurements from 0.1 gauss to 20,000 gausses. The signal is amplified and rectified to operate the meter or external recorder. The final stage uses current feedback to improve the linearity of the meter rectifiers and is powerful enough to drive many DC recorders directly without further amplification. The over-all sensitivity is varied with a front panel CALIBRATE control. A regulated power supply provides the necessary DC power voltage. Semiconductor devices are used for rectification and amplification in all circuits.

TEMPERATURE EFFECTS

As the semiconductor material has a temperature coefficient of resistance about the same as copper, the resistive zero balance of the probe is sensitive to temperature. The zero shift is, of course, greatest on the sensitive 1 gauss range. When the ambient temperature of the probe is changed, the zero should be checked and reset. The zero shift is about one gauss for a 10°C change of temperature on the probe.

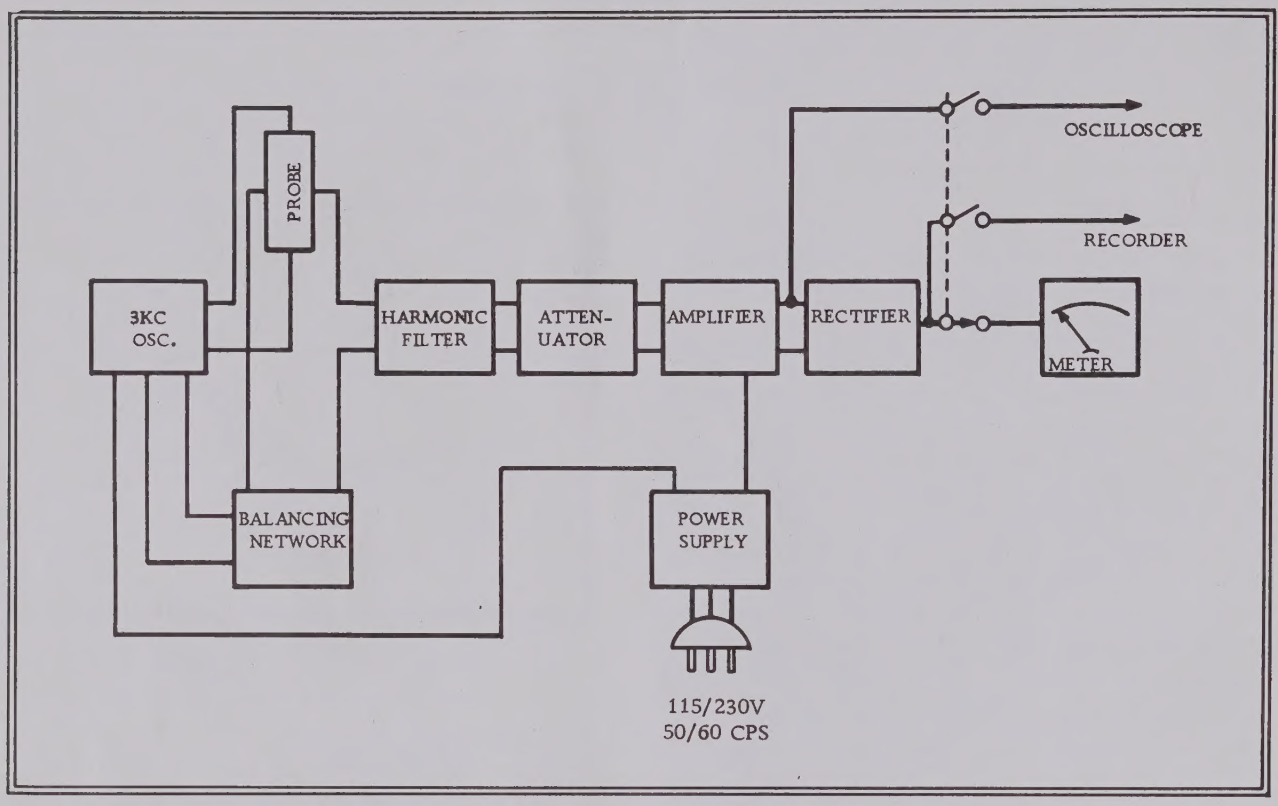


Figure 11. Block Diagram of Model 1890 Gaussmeter.

The Hall coefficient of the InAs material also changes with ambient temperature. The sensitivity of the probe may change approximately 0.1%/°C when submitted to ambient variations after calibrating with a reference magnet. The reference magnets change approximately 0.02%/°C; the magnet will return to its original calibration when normal temperature is restored. An ambient temperature above 180°F may permanently change the calibration of the magnet. A variation in ambient temperature also changes the rectification efficiency of the diodes in the meter circuit. These changes are normally eliminated by calibration at the temperature of use.

PROBE SENSITIVITY

The Hall elements normally used with the Model 1890, as matched to an output load for best linearity, will supply 2.5 mV output when subjected to a 1000-gauss field and driven with 50 mA±20%. The average value of K is 50 x 10^{-6} in the formula: V_H = KHI, where V is the Hall voltage in volts, H is the magnetic field in gausses and I is the current in amperes.

RECEIVER SENSITIVITY

The 3000 c/s input voltage to the filter of the receiver necessary to move the meter to full scale on the 1000-gauss range for each filter tap is given in the next column. These data will be found useful if Hall elements other than those supplied for the instrument are used. The input voltage for any other range is obtained by multiplying the voltage at 1.0 kilogauss by the other full-scale range expressed in kilogauss.

Filter Tap (ohms)	2	3	5	10	20	50
Input Voltage (mV at 1 kilogauss)	2.5	2.75	3	3.8	5	7.6

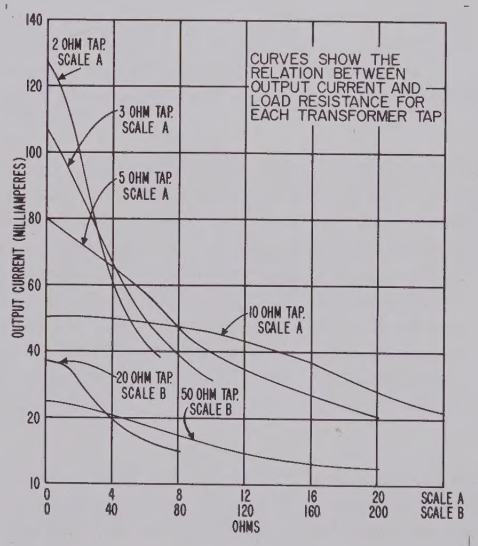


Figure 12. 3000 c/s Oscillator Output.

Operation

UNPACKING THE EQUIPMENT

For shipment in the continental United States, the equipment is packed in commercial cardboard cartons. Upon receipt, the unit should be removed from the carton and inspected for possible physical damage in shipment.

The case of the Gaussmeter is in two halves; they are identical and can be interchanged. Four double-ended butterfly type springs hold the case halves to the front and rear panels. The meter and its easel mount are held on the top of the case by either or both of the case halves. To remove, place the Gaussmeter flat on its right side and lift up the left case half, top and bottom evenly, as shown in Figure 13. The meter and its easel will remain in the right case half as shown.

Figure 14 shows the next step with the meter being withdrawn. The metal tray just below the meter holds the extra cable for oscilloscope or recorder connection and protects the gaussmeter interior when the meter is used in remote location. Most important, it shields the amplifier transistors from the output meter leads when the meter is installed in the top of the Gaussmeter. Be sure it is properly in place when returning the meter to its mounted position. Grommets are provided on the meter cable to fit the slots cut in the tray and the back panel so that the cable may be entirely removed and the case fully closed without the meter. The case may also be closed with meter external and the Gaussmeter operated without the tray when its use requires frequent access to the controls, adjustments, and taps of the oscillator, filter and amplifier within.

No tools are needed to remove or change power supplies. With the fingernail, lift out the tab as marked on the center of the retaining spring, see Figure 15, and the right-hand end of the spring can be disengaged from under the mounting screw. The retaining spring will then turn up, hinging on the left-hand mounting screw, out of the way. The power supply can then be pulled out. When plugging in the battery supply, it is important to note that the terminal contacts are UP so that contact with the top mounted springs within the Gaussmeter will provide connection. Unless specified differently on the purchase order, the AC power supply is connected for 115-volt line operation. Always check transformer connections before plugging into 230 volts; see schematic diagram in back of the book.

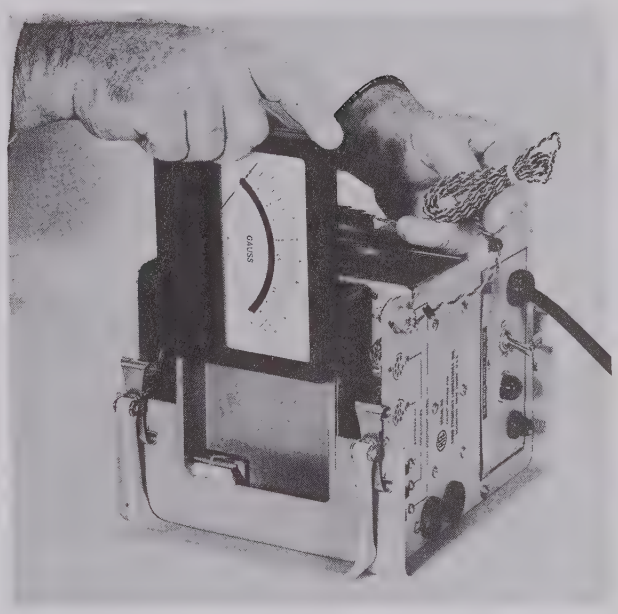


Figure 14. Meter Assembly Slipped Out.

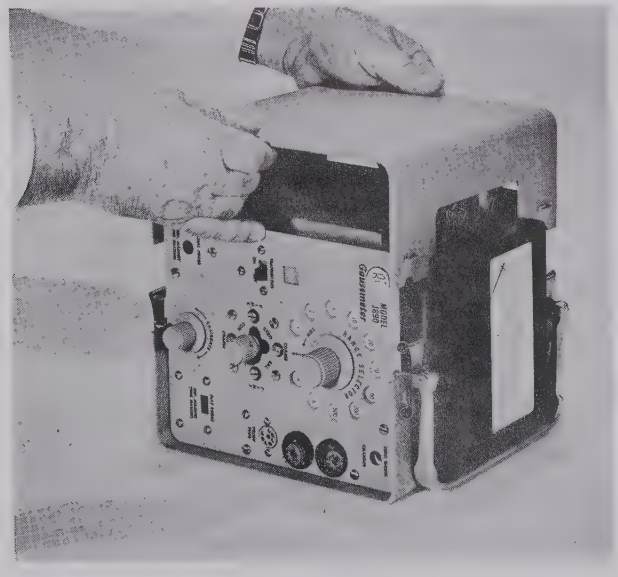


Figure 13. First Step in Opening Case.

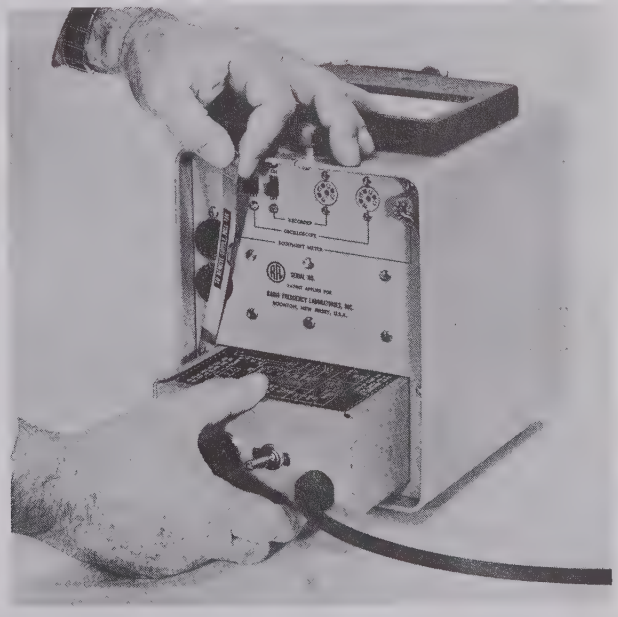


Figure 15. Removal of Power Supply.

CAUTION

InAs elements are brittle, are easily fractured if probe tip is bent, squeezed or flexed. Damaged probes will not be replaced under the equipment warranty.

OPERATION (STEP-BY-STEP)

1. Raise or remove meter from case, as desired. (Make sure it is plugged into its receptacle on back panel and slide switch is ON.)

2. Shift RANGE SELECTOR to LOW position by turning knob fully counter-clockwise; then set white arrow on knob skirt to 1K.

3. Raise ZERO BAL CONTROL and turn it to adjust upper COARSE arrow to point upward in its center position; this is a 3-turn helix and the center position is $1\frac{1}{2}$ turns from full left or full right. Repeat this centering operation for the lower COARSE arrow and both FINE arrows.

4. If AC power supply is used, plug its cord into line receptacle and snap toggle switch (on back of supply) ON.

5. Plug probe into its receptacle on front panel. (When making measurements on the lower ranges, rest a weight on the probe cable to prevent undue cable motion where it enters plug shell.)

6. Slide TRANSISTORS switch ON.

7. Carefully insert probe into ZERO GAUSS CHAMBER, then depress ZERO BAL CONTROL to lower COARSE position and slowly turn it for maximum down scale deflection of the meter. Rotate RANGE switch step-by-step through lower ranges until no closer deflection toward zero meter reading can be accomplished. Then move knob to upper COARSE position and repeat; then repeat with knob in left FINE position and finally in right FINE position with RANGE switch at 1 gauss full scale.

   With all in order, you should be able to balance within three scale divisions of zero on the 1-gauss range. (In actual use, it is unnecessary to zero balance on a lower range than the one which will give the required accuracy. When measuring relatively high fields, balancing outside of the 0-gauss chamber may not significantly affect the desired accuracy, depending on the strength of the ambient field.)

8. Shift RANGE SELECTOR to HIGH or LOW position depending on value of field strength to be measured, and place white arrow opposite full-scale value marked on probe reference magnet (1000 gausses for flat probes or 500 gausses for axial probes).

9. Remove probe from ZERO GAUSS CHAMBER and carefully insert it into center of REF. MAGNET for maximum reading on the meter. With CALIBRATE control adjust reading to exact full-scale value marked on reference magnet. (If flat probe is being calibrated, turn it over 180° and note reading; calibrate to full scale for greatest reading.)

10. Remove probe from REF. MAGNET and place perpendicularly in field to be measured. Rotate RANGE switch to give maximum on-scale reading. Reverse probe in field and select the greatest reading. (Since the Hall voltage varies with the sine of the angle between the plane of the element and the field, direction of stray fields can be plotted.)

11. Turn OFF the equipment by switching OFF the rear toggle switch on the AC power supply and the front panel TRANSISTORS slide switch. When the battery supply is used, the TRANSISTORS switch controls the total battery drain.

If an external 1 MA recorder is used in lieu of the meter, the RECORDER switch is placed ON and the extension cable taken from the storage tray under the meter and plugged into the RECORDER receptacle and connected to the recorder. For oscilloscope connection, the OSCILLOSCOPE switch is placed ON and the extension cable is plugged into the OSCILLOSCOPE receptacle. Pin 7 of the plug is ground.

USE OF PROBE TEST DATA

Unfortunately, the Hall effect of InAs is not linear when subjected to fields from near zero to more than 20K gausses. With careful measurement and loading, elements can be selected to provide all points on their response curves within three meter divisions from 0.1 to 10,000 gausses when calibrated in a single reference magnet. Above 10K gausses the response falls off fairly rapidly, and calibration data or correction factors are necessary. Using the reference magnet supplied, direct reading accuracy on all full scale ranges from one to 10K gausses will be within ±3%. For accuracy approaching ±1%, the meter reading may be corrected with the calibration data.

Where different types of probes are used, check the Test Data Sheet for each to determine the value of reference magnet for calibration. Also check the position of the filter and oscillator taps to make sure the pin plugs within the gaussmeter match the positions given on the Test Data Sheet for that probe.

TEMPERATURE AND STRAIN

On the low gauss ranges, temperature becomes an important factor. Temperature change is given in the probe Test Data Sheet. Also, any mechanical strain applied to the element is readily indicated. Both conditions can be observed by breathing on the probe and lightly touching its end after zero balancing. Moving the cable excessively, especially where it enters the plug body, can cause erratic readings on the 1 gauss range, hence the rea-

son for resting a weight on the cable to anchor it. Short term instability or long term drift not caused by a changing magnetic field are almost always traceable to element temperature changes or mechanical displacement.

FIELD POLARITY

Polarity of magnetic fields up to 100 plus gausses can be determined. This is done by inserting the probe in the 0-gauss chamber and, by adjusting the COARSE ZERO BAL CONTROL, move the meter pointer to the center scale position on the range desired for the sensitivity required. It will then read right or left with field direction.

MEASURING AC FIELDS

For sine wave fields above 50 c/s, multiply the meter reading by the correction factor obtained from the curve in Figure 16. When the probe is placed in an AC magnetic field the meter reads the average value of the field. If the wave shape is of interest, a rear panel oscilloscope switch is provided to switch the rectifier and meter out of the circuit and substitute a 2.2K resistor (R75) for an output load. The oscilloscope output is taken across this resistor and displays the carrier and its envelope. The peak signal can be set at 2 volts for full scale. The output may be termed as double side band with suppressed carrier.

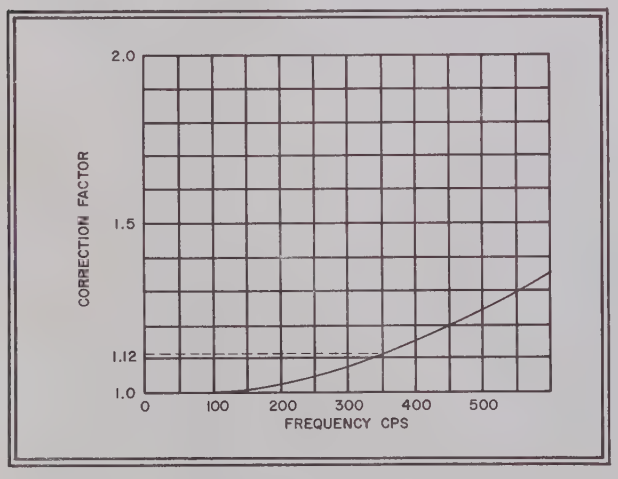


Figure 16. Frequency Response Correction.

ACCURATE MEASUREMENT FROM 10K to 30K GAUSSES

By measurement and loading of selected InAs elements, it is possible to provide single flat probes and calibration curves for accurate (within ±3%) field measurements to 30K gausses. Two choices are presently available: Option "A" and Option "B".

Option "A" - Where single, flat probe magnetic field measurements are to be made from 10K to 20K gausses and maximum accuracy is desired, a calibration curve plotted from 5K to approximately 22K gausses can be purchased with the probe. The curve is in addition to the Probe Test Date Sheet normally supplied. Applying the data from the curve, accuracy of measurement will be within ±3% from 1 gauss to 20K gausses over-all and within ±1% to 2% on many of the ranges.

Option "B" - Where single, flat probe field measurements in the range of 10K to 30K gausses are desired, a selected probe and calibration curve plotted from 5K to 28K gausses can be supplied. A 10K-gauss HB-9657 reference magnet is also required and, using the data from the curve, measurements can be made to an accuracy of ±3% from 5K to 30K gausses. This probe is not calibrated below 5K gausses and, due to its nonlinear characteristics at lower ranges, should not be used for low level work.

SUBSTITUTE REFERENCE MAGNETS

Operation of the Model 1890 Gaussmeter requires a reference magnet for any and all measurements and should include the O-Gauss Chamber when the possibility of ambient or stray fields are strong enough to be a measurable part of the magnetic field to be measured.

All RFL flat probes for Model 1890 Gaussmeter use are selected, matched, resistive loaded and calibrated in a laboratory standard 1000-gauss field. The calibrated values listed on the Probe Data Sheets supplied with each flat probe are based on this 1000-gauss reference and set forth the full range performance of the specific probe when adjusted to zero error at 1000 gausses (±0.5%).

For maximum accuracy, the reference magnet value must be a full scale value available on both the LOW range and HIGH range, since the resistive unbalance between HIGH and LOW settings can be as high as 3%.

Although not advisable, should the user of a Model 1890 Gaussmeter desire to make flat probe measurements without a 1000-gauss reference magnet of at least 3/4% accuracy the following advice is pertinent:

1. Determine the exact value of the substitute reference magnet because, if it is less than 10 gausses or more than 2000 gausses, it cannot be used accurately for both HIGH and LOW ranges. If the probe is calibrated and the RANGE SELECTOR is then shifted (to either HIGH or LOW) an added error up to 3% can be introduced depending upon the resistive unbalance between the LOW and HIGH ranges.

2. In calibrating with the substitute magnet, the Gaussmeter must be adjusted to read the actual value of the magnet corrected by the full scale factor shown for the magnet value on the Probe Data Sheet. If the substitute reference magnet is not a full scale value, the $\frac{1}{2}$% meter tracking error should be considered.

3. Since it is quite likely that the substitute reference magnet has a larger limit of error than the RFL ±0.5% standard magnet used to compile the Probe Data Sheet, its greater tolerance should be considered in calculating the over-all accuracy.

Maintenance

CALIBRATION PROCEDURE

Oscillator HB-13, 385 - As shown in the schematic diagram (foldout at end of book), the oscillator coil L2 has a multi-tap secondary for matching into the current terminals of the Hall element. The position of the pin in SP7 and the matching impedance is given in the test data for each probe. This pin is usually in the 5-ohm tap. The adjustment of the oscillator consists of setting the OSC. GAIN control on the oscillator unit for the specified output or drive voltage across terminals SP10-3 and SP10-1 with the probe in the circuit. For the usual RFL InAs probe this voltage is in the order of 0. 1 volt. The nominal resistance of InAs probes is 2 ohms between the current leads and 1 ohm between the Hall contacts. The 3000 cps. current through the current contact is, therefore, approximately .050 ampere. Figure 17 is a top view of the Model 1890 Gaussmeter showing location of the subunits. Figure 18 shows location of sockets on the Oscillator HB-13, 385.

Hall Probe Elements - Load resistors when required for best linearity to strong fields are determined for each Hall probe and mounted in the connector plug. (See Schematic Diagram.) The procedure for determining the load resistor for a Hall element is to connect a variable resistance box across pins 5 and 7 of socket SP10 (see Schematic Diagram foldout) and adjust the resistance of the box so that full-scale readings on the 1000, 2000, 5000 and 10,000-gauss ranges are within 2% of the full-scale mark. This requires probe reference magnets at the above values. With the probe unloaded, the readings at 5000 and 10,000 gausses will be high by about 4% to 8% when the instrument has been initially set at 1000 gausses. As the shunting resistor is changed, the CALIBRATE control must be reset at 1000 gausses.

A resistive value is selected that places the 5000-gauss range 1% to 2% high and the 10,000-gauss range about 1% low. The value so obtained is Ra and is soldered across pins 5 and 7 of plug P10. A resistor in position Rb may be used to further improve linearity. For most RFL InAs probes this loading resistor (Ra) varies between 3.3 ohms and 15 ohms when the probe is driven from the 5-ohm tap on the oscillator output transformer and the input impedance tap to the filter is set at 5 ohms. The internal driving impedance of the oscillator affects the linearity of the elements and in general should be kept high by using the 5 or 10-ohm output tap with the loading being accomplished with the resistor across the Hall contacts.

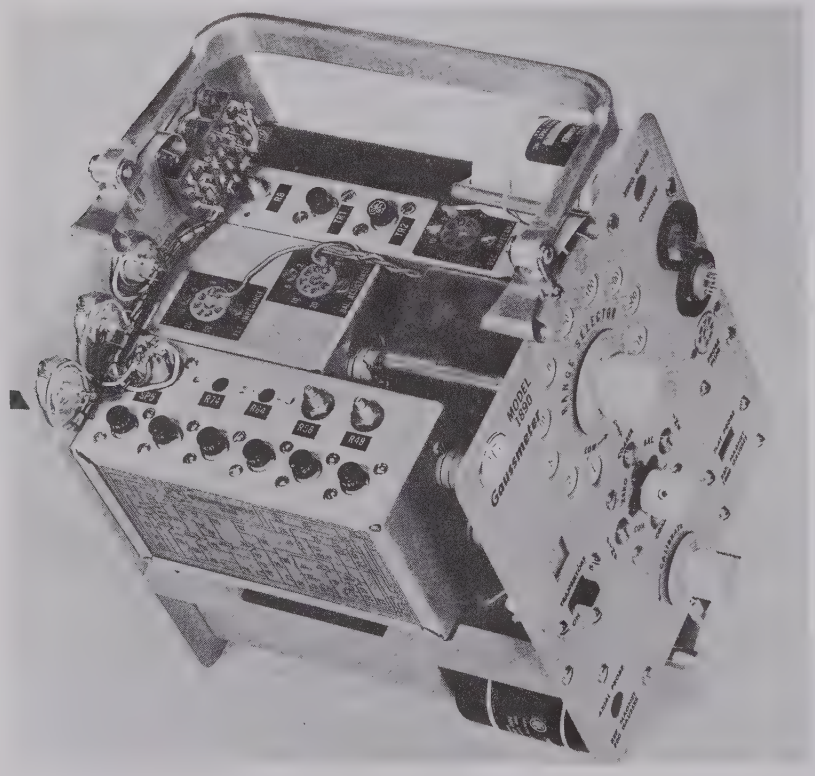


Figure 17.
Top View of
Model 1890 Gaussmeter
Showing Location of Subassemblies.

NOTE

In some cases, damaged probes can still be used on the higher ranges. If partial fracture of the element has occurred, the probe cannot be zero balanced to any useful accuracy on the low ranges but, by checking its zero balance on higher ranges, it can be determined if it will yield useful readings at higher gauss levels. The scale reading above zero to which it can be balanced on a given range will indicate the accuracy of reading on that range.

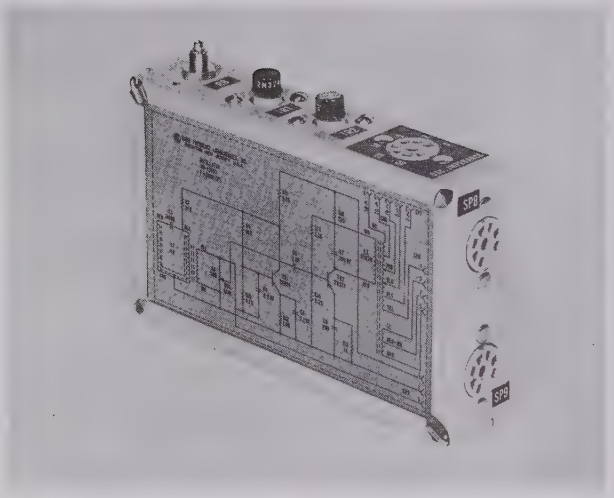


Figure 18.
View of Oscillator HB-13, 385 Subassembly.

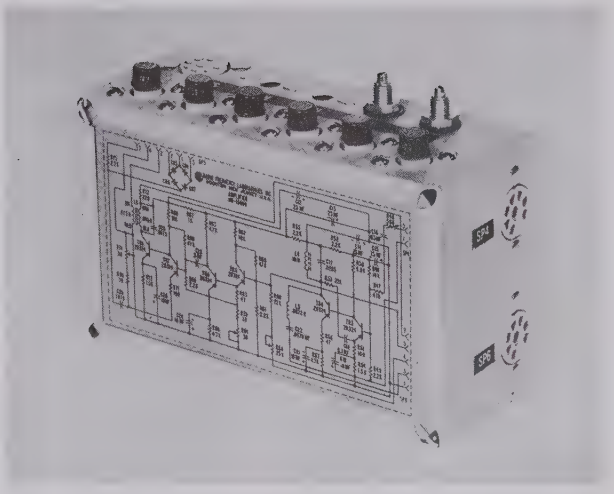


Figure 19.
View of Amplifier HB-13, 400 Subassembly.

Calibration records on each range are provided for the probe and Gaussmeter supplied on each order. These data permit measurements to a greater accuracy than the direct reading accuracy. Probes can be interchanged between units without loss of the direct reading accuracy. For highest accuracy, the probe should be calibrated on the instrument with which it is used. Also, be sure the pin connections are in the proper filter and oscillator taps as given in the Test Data sheet for each probe.

The sensitivity of a probe may be checked by measuring the AC voltage present at the output of the filter on pin 1 of P3 with 1000 gausses applied to the probe. The drive voltage across P8-1 and pin of P7 of the oscillator unit should be set to 0.1 volt. The signal output of the filter should be between .02 and .04 volt as measured between pins 1 and 5 of P3. Pin 5 is ground.

Amplifier HB-13, 400 - The adjustment of the amplifier unit shown in Figure 19 consists of setting the input resistance of the amplifier to 2500 ohms and the setting of 3 gain controls. The input resistance of the amplifier is varied with the ADJ control R48. Place a high impedance vacuum tube voltmeter between pin 1 of the filter at P3 and ground. With the probe plugged in and the RANGE SELECTOR S4 set to 10-gauss range on red scale, adjust the upper COARSE zero control for .004 volt reading. Move the voltmeter to pin 5 of plug P4 on the amplifier subassembly and adjust R48 for a voltmeter reading of .002 volt. Repeat operation until the voltage at pin 5 of plug P4 is $\frac{1}{2}$ the voltage at the filter output. As the multiplier resistor is 2500 ohms $\pm 1\%$, the test operation sets the input to the amplifier to 2500 ohms as required to obtain the correct attenuation on the other gauss ranges.

The over-all sensitivity of the amplifier is adjusted by means of the potentiometers R64, R74 and the CALIBRATE control R76. The maximum sensitivity (CALIBRATE control in maximum clockwise position) is set by varying R74 and R64 on the top of the amplifier until .0045 volt on pin 1 of the filter brings the meter to full scale on the 100-gauss range (S4 on the red ranges). The input voltage is set up

Figure 20.
Rear View of Filter HB-13, 365.

with the upper COARSE zero setting control. The potentiometers R74 and R64 are first set in their mechanical center and both shifted as required to maintain approximately the same gain in each transistor amplifier pair.

The 10:1 sensitivity ratio between the black and red scales of RANGE SELECTOR S4 is adjusted with potentiometer R58 on top of the amplifier subassembly. This control is adjusted so that near full-scale reading is obtained for a 1000-gauss reference magnet on the 1000-gauss red range and also at 1000 gausses on the black range without a change of the CALIBRATE control R76. This adjustment will vary for different probes, as the setting of R58 is not entirely independent of the setting of R76.

NOTE

Shifting from red to black ranges or vice versa after calibrating with the reference magnet and CALIBRATE control may cause an error.

Table 3.
AC Voltage Chart

AC Line Supply

All measurements made with a sensitive vacuum tube voltmeter.

POINTS OF TEST			AC VOLTAGE
(Oscillator)			
P9-3	to	GND	.105
TR1 - B	to	GND	0.1
TR1 - C	to	GND	3.8
TR2 - B	to	GND	.045
TR2 - C	to	GND	4.
SP10-3	to	SP10-1	0.1*
P8-3	to	P8-5	.105
(Amplifier - 1.0 kilogauss range. 1000-gauss field thru probe, black ranges.)			
P3-1	to	GND	.066*
P4-5	to	P4-1	45 μV ±10% CALIBRATE control at max.
			110 μV ±10% CALIBRATE control at max.
TR4 - C	to	GND	.0028
TR5 - C	to	GND	.003
TR6 - C	to	GND	.061
TR7 - C	to	GND	.021
TR8 - C	to	GND	2.4
P5-2	to	GND	2.3

* Will vary with different probes.

Table 4.
DC Voltage Chart

AC Line Supply

Note: As measured with accurate VOM.

POINTS OF TEST			DC VOLTAGE
(Power Supply - 115 v AC)			
Power Supply Contacts			18±10%
(Battery Supply)			18
(Oscillator)			
P9-5	to	GND	19±10%
TR1 - C	to	GND	8.9
TR1 - B	to	GND	1.45
TR1 - E	to	GND	1.42
TR2 - C	to	GND	17.
TR2 - B	to	GND	6.8
TR2 - E	to	GND	6.7
(Amplifier)			
P6-7	to	GND	19.
TR3 - C	to	GND	4.65
TR3 - B	to	GND	.78
TR3 - E	to	GND	.73
TR4 - C	to	GND	9.5
TR4 - B	to	GND	4.75
TR4 - E	to	GND	4.7
TR5 - C	to	GND	4.8
TR5 - B	to	GND	0.2
TR5 - E	to	GND	.15
TR6 - C	to	GND	8.7
TR6 - B	to	GND	4.9
TR6 - E	to	GND	4.8
TR7 - C	to	GND	5.6
TR7 - B	to	GND	.26
TR7 - E	to	GND	.15
TR8 - C	to	GND	17.3
TR8 - B	to	GND	5.2
TR8 - E	to	GND	5.1

Attenuator - A complete check of calibration requires reference magnets for the full-scale reading on each range. The attenuator resistance values are set so that after a calibration is performed on a reference magnet the other full-scale values will fall within ±2%. For maintenance purposes a partial check on the attenuator and probe would be to set the CALIBRATE control for full scale on the 1000-gauss red range with the 1000-gauss reference magnet, then measure this field on the 2000 and 5000-gauss ranges. No adjustment is provided in the attenuator, and a failure in the attenuator will normally require that the equipment be returned to the factory for repair. If a second probe is available, it can be used to check the first probe.

TROUBLE SHOOTING

If trouble develops in the Gaussmeter, follow the Trouble Shooting Chart of Table 5 and make the measurements shown in Tables 3 and 4 to locate the trouble.

Circuit components and subassemblies are located through the use of Figures 17, 18, 19, 20 and the Schematic Diagram (foldout at back of book).

The modular form of the oscillator, the filter, and the amplifier makes their replacement an easier service policy than their repair within the equipment. The Gaussmeter is more quickly put back in service. For those who have more than one Gaussmeter, extra units may well be kept for immediate service while the faulty module is returned to RFL for repair.

Table 6 Replaceable Parts List is for your convenience in ordering replacements when necessary.

Table 5.
Trouble Shooting Chart

TROUBLE	POSSIBLE CAUSE	REMEDY
Operation on 115 volts AC power. No pilot lamp.	Blown fuse, faulty plug P14.	Check for shorts in the power supply and replace fuse. Measure DC output of power supply to be 18 volts ±10%.
ZERO BAL. CONTROLS have little or no effect on zero on the 10-gauss ranges.	Open potential leads in probe E1 or open cable W1.	Check by shorting pins 5 and 7 of SP10 together and observing actions of controls. If no action, trouble shoot the amplifier. Replace faulty probe if controls operate the meter.
	Oscillator not functioning.	Check AC voltage between pins 1 and 3 of connector SP10 (E1 removed). If no voltage, trouble shoot the oscillator circuit and power supply.
	Open current leads in probe E1.	Measure with ohmmeter and replace probe E1.
No oscillator output voltage	Defective component in oscillator subassembly. Defective DC power supply circuit.	Trouble shoot oscillator circuit using Tables 3 and 4 for guides as to voltages. Trouble shoot power supply circuit.
Low voltage of approximately .025 volt on pin 1 of P3 for 1000 gausses on normal probe.	Defective filter.	Remove filter connections and test with 50 ohms input impedance and 5000 ohms on output. The step-up ratio is approximately 10. Bandwidth about 1000 cycles. Center frequency of 3000 cycles. Replace filter if defective.
No amplifier output indicated by meter.	Defective component in amplifier or meter circuit.	Signal trace circuit by applying 3000-cycle signal to input terminals P4-5 and P4-1 and use Tables 3 and 5 as voltage guides.

Table 6. Table of Replaceable Parts

RFL PART NO.	DESCRIPTION	QUAN.	DIAGRAM SYMBOL
HA-9362	ADAPTER: 3-wire plug to 2-wire recept.	1	
H-1007-167	CAPACITOR, mylar: .25 mf, 200 v, ±10%	1	C1
H-1080-244	CAPACITOR, sil. mica: .005 mf, 500 v, ±10%.	1	C2
HA-16310	CAPACITOR, sil. mica: .0068 mf, 500 v, ±2%	1	C3
H-1080-248	CAPACITOR, metallized paper: 2 mf, 50 v, ±20%.	1	C5
H-1080-289	CAPACITOR, metallized paper: 3 mf, 50 v, ±20%	1	C8
H-16034	CAPACITOR, mylar: .051 mf, 200 v ±2%.	1	C7
H-1007-207	CAPACITOR, electrolytic: 25 mf, 50 v.	2	C9, 10
HA-6632	CAPACITOR, electrolytic: tubular, plastic-cased 25 mf, -10% +250%, 25 VDC.	6	C11 to 15, C19
HA-13167	CAPACITOR, electrolytic: 10 mf, 25 v, -10% +250%.	5	C4, C6, C21, C24, C26
H-1007-211	CAPACITOR, paper: .5 mf, 200 v.	3	C16, C23, C27
HA-16021	CAPACITOR, mylar: .0285 mf, 200 v, ±2% (matched to toroid).	1	C17
H-1007-64	CAPACITOR, paper: .1 mf, 200 v, ±20%.	1	C18
HA-12971	CAPACITOR, met. paper: 1 mf, 200 v, ±20%.	1	C20
HA-16032	CAPACITOR, mylar: .0470 mf, 200 v, ±2% (matched to toroid).	1	C22
HA-16027	CAPACITOR, mylar: .0375 mf, 200 v, ±2% (matched to toroid).	1	C25
HA-16000	CAPACITOR, mylar: .01 mf, 200 v, ±2% (matched to toroid).	1	C28
HA-13958	CAPACITOR, sil. mica: .0036 mf, 500 v, ±2% (matched to toroid).	1	C29
HA-9359	CHOKE: 4.5 hy, 50 ma, 200-ohm.	1	L3
HB-8515-7	COIL, toroid, oscillator: .4 hy.	1	L1
HB-11203	COIL, toroid, oscillator output: .0563 hy, 3000 cps, 666 t.	1	L2
HB-8514-275	COIL toroid, tuned: .111 hy (HA-11752 COIL, tuned, amp. filter).	1	L4
HB-8514-276	COIL, toroid, tuned: .0672 hy (HA-11753 COIL, tuned, amp. filter).	1	L5
HB-8535-176	COIL, toroid, dual winding: .075 hy (HA-11751 TRANSFORMER OUTPUT).	1	L6
HB-11204	COIL, toroid: .208 hy.	1	L7

Table 6. Table of Replaceable Parts (Continued)

RFL PART NO.	DESCRIPTION	QUAN.	DIAGRAM SYMBOL
HB-8514-270	COIL, toroid, tuned: .796 hy.	1	L8
HA-10271	DIODE, silicon: F2.	2	CR1, CR2
HA-13918	DIODE, silicon: (negative stud), 10M19Z10.	1	CR3
HA-13242	DIODE, HD-2155.	4	CR4 to CR7
HA-9348	FUSE: 1/2 amp, 3 AG	1	F1
HA-1816	FUSEHOLDER	1	
HA-8752	KNOB: round dial, grey, skirted.	1	
HA-13251	KNOB: unskirted, grey, 11/16 dia. x 3/4 high standard control, round, mirror finish.	1	
HA-9949	KNOB: skirted, grey.	1	
HA-2468	LAMP, glow.	1	I2
HA-9269	LAMP, panel.	1	E2
HB-9361	LINE CORD.	1	P14
HB-9272	MAGNET, reference: flat probe, 1000-gauss.	1	
HB-11279	MAGNET, reference: axial probe, 500-gauss.	1	
HB-12599	METER, Weston Model 1951	1	
HA-13260	PLUG: tube base.	9	P3 to P6, P8, P9, P11 to P13
HB-13460	PROBE, InAs, flat, and SCABBARD.	1	
HB-13470	PROBE, InAs, axial.	1	
HA-11240	REFERENCE CHAMBER, zero gauss.	1	
H-1009-496	RESISTOR, fixed comp: 47 ohms, 1/2 w, ±10%.	3	R1, R56, R63
HA-13253	RESISTOR, variable: 3 turns, 50 ohms.	1	R2
H-1009-350	RESISTOR, fixed comp: 4.7K, 1/2 w, ±10%.	5	R3, R10, R57, R65, R66
HA-9344	RESISTOR, variable WW: 100 ohms, 2 w, ±5%, 1/2 " long round shaft w/hardware.	3	R4 to R6
H-1009-631	RESISTOR, fixed comp: 24K, 1/2 w, ±5%.	1	R7
HA-13240	RESISTOR, variable: 500 ohms, .3 w, ±30% "A = 3/8 x 1/4 -32" "L = 1/2 inch" screwdriver slot w/hardware.	2	R8, R48
H-1009-639	RESISTOR, fixed comp: 18K, 1/2 w, ±10%.	2	R9, R46
H-1009-640	RESISTOR, fixed comp: 6.8K, 1/2 w, ±10%.	2	R11, R50

Table 6. Table of Replaceable Parts (Continued)

RFL PART NO.	DESCRIPTION	QUAN.	DIAGRAM SYMBOL
H-1009-446	RESISTOR, fixed comp: 1.8K, 1/2 w, ±10%.	1	R12
H-1009-419	RESISTOR, fixed comp: 3.3K, 1/2 w, ±10%.	1	R13
H-1009-434	RESISTOR, fixed comp: 2.2K, 1/2 w, ±10%.	7	R14, R49, R52, R55, R61, R68, R75
H-1009-544	RESISTOR, fixed comp: 220 ohms, 1/2 w, ±10%.	2	R16, R72
H-1510-320	RESISTOR, metal film: axial lead, 0.47 ohm, ½ w, ±5%.	1	R19
H-1510-321	RESISTOR, metal film: axial lead, 0.51 ohm, ½ w, ±5%.	1	R20
H-1510-322	RESISTOR, metal film: axial lead, 1 ohm, ½ w, ±5%.	1	R21
H-1510-323	RESISTOR, metal film: axial lead, 3 ohms, ½ w, ±5%.	1	R22
H-1510-324	RESISTOR, metal film: axial lead, 5.1 ohms, ½ w, ±5%.	1	R23
H-1510-325	RESISTOR, metal film: axial lead, 10 ohms, ½ w, ±5%.	1	R24
H-1510-207	RESISTOR, fixed, carbon film: miniature 2.5K, 1/4 w, ±1%.	2	R25, R35
H-1510-221	RESISTOR, fixed, carbon film: miniature 3.75K, 1/4 w, ±1%.	1	R26
H-1510-251	RESISTOR, fixed, carbon film: miniature 4.50K, 1/4 w, ±1%.	1	R27
H-1510-210	RESISTOR, fixed, carbon film: miniature 4.75K, 1/4 w, ±1%.	1	R28
H-1510-211	RESISTOR, fixed, carbon film: miniature 24.375K, 1/4 w, ±1%.	1	R29
H-1510-212	RESISTOR, fixed, carbon film: miniature 24.75K, 1/4 w, ±1%.	1	R30
H-1510-213	RESISTOR, fixed, carbon film: miniature 8.333K, 1/4 w, ±1%.	1	R31
H-1510-214	RESISTOR, fixed, carbon film: miniature 199K, 1/4 w, ±1%.	1	R32
H-1510-263	RESISTOR, fixed, carbon film: miniature 5.194K, 1/4 w, ±1%.	1	R33
H-1510-252	RESISTOR, fixed, carbon film: miniature 400K, 1/4 w, ±1%.	1	R34
H-1510-256	RESISTOR, fixed, carbon film: miniature .625K, 1/4 w, ±1%.	2	R36, R41
H-1510-253	RESISTOR, fixed, carbon film: miniature .2775K, 1/4 w, ±1%.	2	R37, R39
H-1510-220	RESISTOR, fixed, carbon film: miniature .833K, 1/4 w, ±1%.	1	R38
H-1510-255	RESISTOR, fixed, carbon film: miniature 1.666K, 1/4 w, ±1%.	1	R40
H-1510-257	RESISTOR, fixed, carbon film: miniature .2175K, 1/4 w, ±1%.	2	R42, R43
H-1510-254	RESISTOR, fixed, carbon film: miniature .1043K, 1/4 w, ±1%.	1	R44
H-1100-243	RESISTOR, WW: 300 ohms, 10 w, ±5%.	1	R45
H-1009-497	RESISTOR, fixed comp: 330 ohms, 1/2 w, ±10%.	1	R47
H-1009-435	RESISTOR, fixed comp: 100 ohms, 1/2 w, ±10%.	2	R51, R71

Table 6. Table of Replaceable Parts (Continued)

RFL PART NO.	DESCRIPTION	QUAN.	DIAGRAM SYMBOL
H-1009-430	RESISTOR, fixed comp: 22K, 1/2 w, ±10%.	1	R53
H-1009-418	RESISTOR, fixed comp: 1.5K, 1/2 w, ±10%.	2	R54, R73
HA-13241	RESISTOR, variable: 25K, .2 watt, ±30% "A = 3/8 x 1/4-32" "L = 1/2 inch" screwdriver slot w/hardware.	1	R58
H-1009-442	RESISTOR, fixed comp: 47K, 1/2 w, ±10%.	2	R59, R70
H-1009-605	RESISTOR, fixed comp: 15K, ±10%, 1/2 w.	1	R60
H-1009-391	RESISTOR, fixed comp: 10K, 1/2 w, ±10%.	2	R62, R69
HA-11264	RESISTOR, variable: tab mtg. sens. for printed circuits, 50 ohms, .3 w.	2	R64, R74
H-1009-429	RESISTOR fixed comp: 1K, 1/2 w, ±10%.	2	R15, R67
HA-13250	RESISTOR, variable, WW: tandem w/200 ohms to panel - 1500 ohms on back, ±10%, linear taper, bushing 3/8- 32 x 3/8", shaft 1/4 round x 1/2" lg. from end of bushing.	1	R76
H-1009-473	RESISTOR fixed comp: 680 ohms, 1/2 w, ±10%.	2	R77, R78
HA-13252	RESISTOR, comp: 39 ohms, 1/2 w, ±10%.	2	R79, R80
HA-13257	SOCKET, transistor.	8	XTR1 to XTR8
HA-13258	SOCKET, 7 pin min.	5	SP1, SP2, SP5 to SP7
HA-13259	SOCKET, (without contact springs 2, 4 and 6). 7 pin. min.	8	SP3, SP4, SP8 to SP13
HB-13412	SWITCH, rotary: 3 pole, 12 pos., 3 deck.	1	S4
HA-9267	SWITCH, slide: DPDT	5	S1 to S3, S6, S7
HA-9372	SWITCH, toggle: DPST, bat handle.	1	S5
HA-9356	TRANSFORMER, power.	1	T1
HA-9365	TRANSISTOR, power: type 2N324.	7	TR1, TR3 to TR8
HA-3166	TRANSISTOR, PNP: 2N321	1	TR2
HA-13330	TUBE, probe storage.	2	
HB-13311	TRAY, meter compartment.	1	

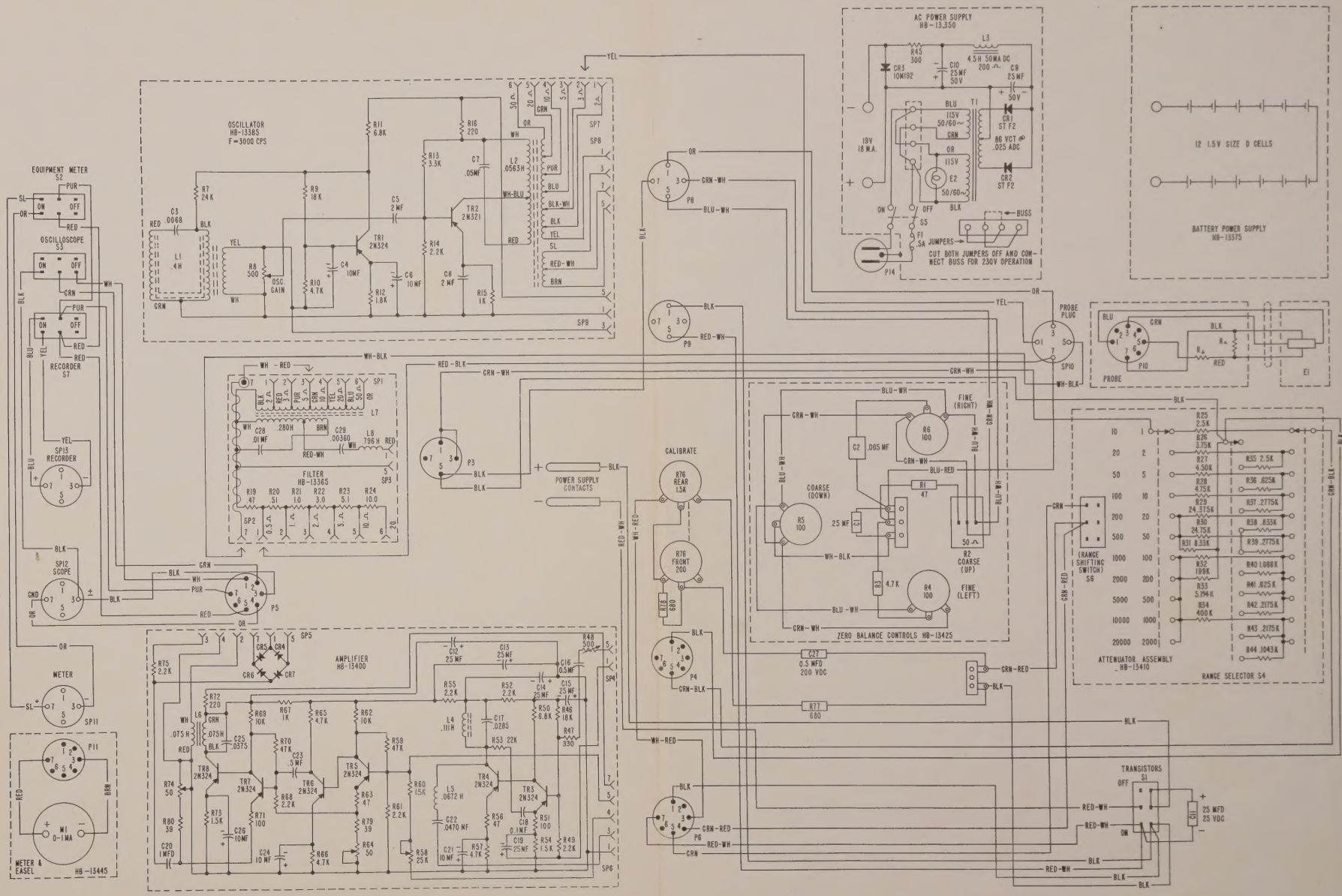
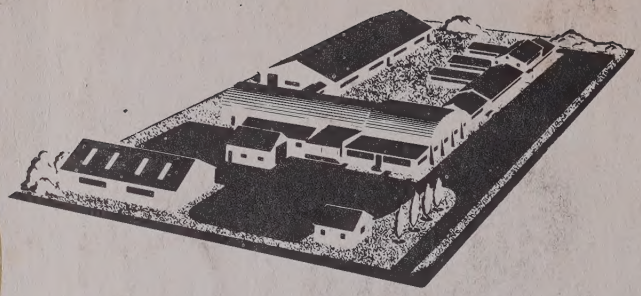


Figure 21. Schematic Wiring Diagram of Model 1890 Gaussmeter.



Warranty

The Model 1890 Gaussmeter carries a warranty of 12 months from date of delivery for replacement of any part, except probes, which fails during normal operation or service. A deficient part should be returned to the factory, shipping charges prepaid, for replacement f. o. b. Boonton, N. J.

Radio Frequency Laboratories, Inc.
BOONTON, NEW JERSEY, U.S.A.

6351D

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